OSA-2449-71

30 October 1971

MEMORANDUM FOR THE RECORD

SUBJECT: Trip Report 19-21 October 1971

1. Locations and Purposes of Visits:

The undersigned visited the ARO Corporation in Buffalo, New York, on 19 October 1971 and the David Clark Company in Worcester, Massachusetts, on 20 and 21 October 1971. Discussions were conducted with the plant managers at both facilities on the status of Life Support equipment in general and on new development efforts and modifications to existing equipment.

2. Results of Visits:

(a) ARO Corporation:

Discussions with plant engineers resolved the controller leak rate discrepancy with a promise to improve the quality control on new controllers and limit the maximum leak rate in all controllers to 1800 cc/min. [redacted] of Headquarters contracts branch reviewed the status of the ARO contract AB-2303 including all four task orders, active ECP's, and proposed service bulletins.

(b) David Clark Company

The Omni-Environmental pressure suit and helmet feasibility study was reviewed and factory engineers presented some new concepts in helmet and neck ring design that are being considered for the next

generation full pressure suit. A service bulletin is being prepared to change the color on the bottom of the one-man life raft to black in order to provide better protection from shark attack (see attachment). A flotation test of approximately one hour was accomplished in a nearby lake utilizing an improved design in pressure suit and flotation cell integration with the undersigned as test subject. Finally, the relative merits and deficiencies of standard sizing of pressure suits versus custom fit suits were discussed, including cost involved and lead time necessary to have suits available on the shelf.

[redacted] 25X1
AMS/OSA

Attachment
As stated above

CONCURRENCE AND/OR COMMENT

25X1 [redacted]
C/AMS/OSA

AMS/OSA/[redacted] 25X1
Distribution:

1 - AMS/OSA
1 - " Chrono
1 - CMD/OSA
1 - D/M/OSA
1 - RB/OSA

COLOR AND REFLECTIVITY OF SEA SURVIVAL EQUIPMENT AS RELATED TO SHARK ATTACK

Ernest B. McFadden, Civil Aeromedical Institute, Federal Aviation Administration
Scott Johnson, Ph.D., Naval Undersea Research & Development Center

INTRODUCTION

Development of sea survival equipment such as life rafts, vests and canopies has emphasized the requirements for a high degreee of conspicuity through the use of materials of a bright hue, contrast, and reflectivity to aid in the search and rescue of aircraft ditching survivors. Even with the event of more sophisticated signalling devices, allowing long range location and detection, the continuous visual acquisition desired within the immediate recovery area is influenced by the conspicuity of the survivors and their equipment. Conversely, military missions may require minimization of contrast and conspicuity in order to avoid detection by the enemy.

With respect to factors influencing shark behavior, there is mounting evidence that the degree of brightness and conspicuity as detected by the visual sense of sharks may promote or passively deter attack.

Gilbert[1] in 1962 stated that the sense of sight is the research target of what appears to be the only effective, although not universally practicable, shark repellent.

Adult and child life preservers fail to provide adequate protective capability when worn by infants or small children exposed to high seas and an adverse thermal environment. To provide increased protection, a simple lightweight life-support infant flotation device was designed at the Civil Aeromedical Institute and previously described.[2,3]

Life support design criteria have been tested and evaluated,[2,3] with the exception of those factors influencing shark attack. This paper is addressed to the factor of shark attack upon this device and other flotation means.

Some of the concepts of the Johnson Shark Screen were inherent in the infant flotation device design. Previous evaluations of the Johnson Shark Screen indicated that the darker, non-reflective bags of large size and indefinite shape which conceal the human form appear to deter shark attack.[4,5] However, the infant flotation device differs in that it is much smaller and, because of thermal and ventilatory requirements, does not completely conceal the human form.

METHODS

Two prototype infant flotation devices were fabricated, one incorporating a black, non-reflective immersed surface and the other a brightly-colored immersed surface. The immersed portion of the brightly-colored device consisted of a lower tapered neoprene foam bag of a bright red color supported by a bright yellow inflatable ring. In a previous study,[3,6] these two prototypes occupied by an anthropomorphic dummy or primate were repeatedly exposed to captive coastal and bottom-feeding sharks in the Mote Marine Laboratory shark pens, Siesta Key, Florida. As a control, a typically-clothed anthropomorphic child dummy equipped with a standard yellow airline life preserver was simultaneously exposed. Species used in these experiments included brown sharks (*Carcharhinus milberti*), tiger sharks (*Galeocerdo cuvieri*), and bull sharks (... are known to be dangerous to man. This study indicated these devices should also be exposed to sharks in their natural habitat.

In cooperation with the Naval Undersea Research and Development Center, a second series of evaluations of the infant flotation device, consisting of exposing these devices and controls to pelagic sharks in their natural habitat, was carried out using the Center's underwater observatory vessel, the "See-Sea." This ingenious and valuable research tool is equipped with a retractable underwater transparent capsule accommodating two observers in a shirt-sleeve environment and permitting nearly 360-degree observation and photography. In this series of tests, sharks were attracted to an area by introducing small quantities of a dilute solution of homogenized bonito. The test items simultaneously introduced into the water consisted of a black, non-reflective infant flotation device; a child dummy wearing a yellow life vest; a bright red infant flotation device; and a child dummy wearing a yellow life vest, spray painted a dull black. Each of the devices was tethered to the vessel and an attempt was made to maintain consistent separation and relative position.

RESULTS

The captive brown, tiger, and bull sharks utilized in the tests at the Mote Marine Laboratories, even though having been maintained in captivity in some instances for several months, refused to feed. However, on the basis of interest as determined by the frequency of bumps and passes, it was concluded that the infant flotation device was markedly less attractive to sharks than an anthropomorphic dummy in a standard life vest.[6]

Exposing these devices to sharks in their natural environment revealed a considerably more aggressive behavior. The standard yellow life vest occupied by an anthropomorphic child dummy was repeatedly and consistently attacked on the surface by blue sharks (*Prionace glauca*). In most instances the legs, arms, and body of the child dummies were not attacked by blue sharks until after the vest was attacked, deflated, and the dummy had sunk below the surface. Frequently, the attack on the yellow vest continued even after the dummy had sunk. Some dozen yellow life preservers were destroyed or damaged beyond repair in these attacks.

The yellow ring on the red infant flotation device was bitten twice by blue sharks, once being near the shiny chrome-plated carbon dioxide cylinder. During these attacks, the lower red portion of the device suffered one bite. In one instance, the blue sharks were stimulated to a state of excitement (olfactory-induced frenzy-biting of each other, etc.) by accidental introduction of a large quantity of concentrated bonito homogenate. The lower portion of the black infant flotation device, located in the middle of this melee, was apparently indistinguishable from other combatants in the immediate area and suffered its only bite during the tests. One other ... near the

shiny CO_2 cylinder. The cylinders on the black infant flotation device and life vest were subsequently painted dull black. No further attacks occurred on these devices.

Mako (Isurus oxyrinchus) sharks appeared occasionally in the area, but circled at the limits of visibility (50-100 feet). No more than three were observed in the area at any one time, whereas as many as 45 blue sharks collected in the area without fear of the vessel or the underwater observatory. Mako sharks were observed to make a high-speed attack from below with teeth bared and snapping jaw motions just prior to contact with their target, without exhibiting the preliminary surface behavior characteristic of the blue sharks. Three principal attacks by Mako sharks were made on the anthropomorphic dummy equipped with a yellow jacket. In one instance, the arm was torn from the dummy and appeared to be ingested. Mako sharks did not attack either of the infant flotation devices or the child dummy equipped with a black life vest, but in each instance selected the anthropomorphic dummy wearing a standard yellow life vest.

The anatomy of the shark's eye indicates that reflectivity and contrast play a major role in its feeding behavior. Cones have been demonstrated in the retina of only a few species of sharks, and they are outnumbered by rods as much as 150 to 1. Since the retina of the majority of sharks is cone-free, and lacks both area centralis and fovea,[7] it may be concluded that sharks are incapable of perceiving color and have a vision of low acuity. On the other hand, rods are very abundant, and in multiples convey their impulses to a single bipolar or ganglion cell, producing summation of impulses.[7] This results in an eye with great sensitivity, which, although low in visual acuity, can readily detect an object or movement against a contrasting background in the dimmest of light. This high degree of sensitivity is further enhanced by the tapetum lucidum, a mirror-like layer underlying the retina consisting of guanine crystals which reflects incoming light back through the retina, restimulating the rods. Other special structures and mechanisms aid in light and dark adaptation.[1,7] There are two additional major sensory systems. The lateralis system consists of fine canals lying just beneath the skin on both sides of the body. These canals are lined with clusters of neuromasts from which hairlike structures extend into the fluid-filled canal. This very sensitive vibration sensing system appears to be capable of detecting vibrations or disturbances such as the splashing of injured fish at considerable distances -- possibly many miles in the case of sea disasters when water impact or explosions are involved. Olfaction is facilitated by water continuously passing through the nostrils and olfactory sacks which exhibit a very large surface area, enabling the shark to detect an odorous substance in concentrations as low as one part in several million. It is thought that the vibration and olfactory senses are of primary value for sensing and locating a prey from a considerable distance, whereas once located, the visual sense plays a major role in the actual attack.

Conspicuity for reasons of search and rescue is of prime importance and it is not recommended that all life preservers be manufactured of a non-reflective black material. However, methods of presenting a less attractive target to the shark and simultaneously presenting a contrasting, conspicuous, image to surface search and rescue personnel should be pursued. Large inflatables are not immune to attack. In addition to a measured bite strength in excess of 18 metric tons,[1] some sharks are capable of protruding the jaw following which they frequently attack attractive inanimate objects with a slashing motion of their head.

In an effort to maximize efficiency and reliability of flotation equipment, airlines plan on expending millions of dollars in outfitting civil transport aircraft with combination slide/rafts. Those slide/rafts, some of which accommodate fifty to sixty survivors and are considered to be non-reversible, should employ a dark non-reflective submerged surface. The effectiveness of a thin-lightweight skirt, or streamers of a thin black non-reflective film, deployable around the periphery of the raft or possibly even from a life jacket should be explored.

CONCLUSIONS

1. Methods for rendering life vests and reversible life rafts a less conspicuous and attractive visual target for shark attack should be explored.
2. Highly-reflective and attractive hardware such as chrome-plated carbon dioxide inflation cylinders, buckles, and snaps normally found on life vests should be of a black non-reflective material.
3. The submerged portion of life rafts or slide rafts considered non-reversible should be of a black non-reflective material.

REFERENCES

1. Gilbert, P.W. The Behavior of Sharks, Scientific American, July 1962.
2. McFadden, E.B., Simpson, J.M., and Wolfenspar-ger, D.L. Protection of Infants in Aircraft Ditching, Preprints of Scientific Program, 36th Annual Scientific Meeting, pp. 208-209 Aerospace Medical Association, Americana Hotel, Bal Harbor, Fla., May 6-9, 1968.
3. McFadden, E.B., Young, J.W. Evaluation of An Improved Flotation Device for Infants and Small Children, Proceedings of Eighth Flight Safety, Survival and Personal Equipment Symposium, Volume II, pp.341-348, Las Vegas, Nev., Sept 28-Oct.1, 1970.
4. Gilbert, P.W. Report on the Use of the Johnson Shark Screen as a Deterrent to Sharks, U.S. Naval Ordnance Test Station, W.O. P060530/5000Y0944-66, Div. of Biology, Cornell Univ., Ithaca, N.Y., Nov. 1, 1966.
5. Tester, A.L., Nelson, G.J., and Daniels, C.L. Tests of NOTS Shark Deterrent Device, U.S. Naval Ordnance Test Station, W.O. P060530/5000Y0943-66, Univ. of Hawaii, Honolulu, Hawaii, Aug.15, 1966.
6. Gilbert, P.W., Martini, F., and Irvine, B. Final Report of Reaction of Adult Sharks Known to Be Dangerous to Man to an Infant Flotation Device FAA P.O. OAC-48688-M Mote Marine Laboratory, Sarasota, Fla., March 18, 1970.
7. Gilbert, P.W. Sharks and Survival, pp.312-314 1963, D. C. Heath & Co., Boston.